

WHAT IS CLAIMED IS:

1. A monitoring system comprising:  
an implantable medical device configured to be implanted in a  
patient to provide a stimulus to the patient; and  
5 a monitor having processing circuitry configured to detect a  
radio frequency artifact from the stimulus of the implantable medical device  
in order to eliminate an occurrence of falsely identifying voltage artifact as a  
heart beat.

2. The monitoring system of Claim 1 wherein the processing  
10 circuitry is configured to exclude the artifact from heart rate determinations.

3. The monitoring system of Claim 1 wherein the implantable  
medical device is a pacemaker.

4. The monitoring system of Claim 3 wherein the monitor detects  
radio frequency by radio telemetry from a remote location relative to the  
15 patient.

5. The monitoring system of Claim 1 wherein the monitor is  
externally attachable to a patient.

6. The monitoring system of Claim 1 wherein the monitor is  
configured to receive telemetry pacemaker electrograms recorded directly  
20 from the heart.

7. The monitoring system of Claim 1 wherein the monitor  
comprises an antenna to detect the radio frequency artifact.

8. The monitoring system of Claim 7 wherein the antenna is integrated into an ECG electrode.

9. The monitoring system of Claim 1 wherein the processing circuitry comprises a slew limit circuit to limit pace artifact energy in the  
5 signals.

10. The monitoring system of Claim 9 wherein the processing circuitry is configured to monitor multiple channels of the signals.

11. The monitoring system of Claim 10 wherein the processing circuitry comprises a tunable band pass filter to isolate the voltage artifact  
10 from ambient noise.

12. The monitoring system of Claim 11 wherein the tunable band pass filter may be configured according to variations in gain, center frequency and band width.

13. The monitoring system of Claim 12 wherein the tunable band  
15 pass filter is configured automatically.

14. The monitoring system of Claim 12 wherein the tunable band pass filter is configured manually by a user.

15. The monitoring system of Claim 9 wherein the processing circuitry is configured to automatically select from alternative sets of quasi  
20 orthogonal ECG leads in the event of different patient cable attachments or electrode failures.

16. The monitoring system of Claim 15 wherein selection is accomplished by a multiplexor hardware circuit.

17. The monitoring system of Claim 15 wherein selection is accomplished by software when all channels have been digitized.

18. A monitoring system comprising:  
a monitor configured to detect a radio frequency artifact from  
5 the signals of an implantable medical device; and  
processing circuitry configured to process the radio frequency artifact from signals of the implantable medical device in order to determine where artifact occurs in an ECG and identify heart beats that are paced and heart beats that are not paced and occurrences of pacing that fail to  
10 stimulate a heart beat.

19. The monitoring system of Claim 18 wherein the processing circuitry is configured to exclude artifact from heart rate determinations.

20. The monitoring system of Claim 19 wherein the processing circuitry is configured to classify pacing stimuli according to heart chamber  
15 location.

21. The monitoring system of Claim 20 wherein the processing circuitry comprises a slew limit circuit to limit pace artifact energy in the signals.

22. The monitoring system of Claim 20 wherein the processing  
20 circuitry is configured to monitor multiple channels of the signals.

23. The monitoring system of Claim 20 wherein the processing circuitry comprises a tunable band pass filter to isolate the voltage artifact from ambient noise.

24. The monitoring system of Claim 20 further comprising an implantable medical device configured to be implanted in a patient to provide a stimulus to the patient.

25. A circuit for processing voltage artifact from implantable  
5 pacemaker signals comprising:  
a slew limit circuit to limit pace artifact energy in the signals;  
and  
a tunable band pass filter operable in parallel to the slew limit  
circuit and configured to isolate the voltage artifact from ambient noise and  
10 heart signals.

26. The circuit of Claim 25 wherein the circuit is configured to monitor multiple channels of the signals.

27. The circuit of Claim 25 wherein the tunable band pass filter may be configured according to variations of gain, center frequency and band  
15 width.

28. The circuit of Claim 27 wherein the tunable band pass filter is configured automatically.

29. The circuit of Claim 27 wherein the tunable band pass filter is configured manually by a user.

20 30. The circuit of Claim 25 further comprising a timing circuit that measures the duration of pulses.

31. The circuit of Claim 25 wherein a data channel is sampled at a rate in the range of about 18,000 to about 150,000 samples per second and pace detection is principally a digital processing algorithm.

32. The circuit of Claim 25 wherein pace channel data is amplified by a linear or piece wise linear or logarithmic function and peak stretched and converted from analog to digital.

33. The circuit of Claim 25 wherein the circuit is configured to  
5 process radio frequency artifact from signals of the implantable pacemaker device in order to identify where pacing stimulus artifact occurs in an ECG and determine which heart beats are paced and which heart beats are not paced and occurrences of pacing that fail to stimulate a heart beat.

34. The circuit of Claim 33 wherein the circuit is configured to  
10 exclude pacing stimulus artifact from heart rate determinations.

35. The circuit of Claim 34 wherein the circuit is configured to classify pacing stimuli according to heart chamber location.

36. A method of monitoring signals from an implantable medical device that provides a stimulus to a patient comprising:

15 detecting a radio frequency artifact from the implantable medical device; and

processing the radio frequency artifact from the implantable medical device in order to determine where artifact occurs in an ECG and identify heartbeats that are paced and heartbeats that are not paced and  
20 occurrences of pacing that fail to stimulate a heart beat.

37. The method of Claim 36 further comprising excluding artifact from heart rate determinations.

38. The method of Claim 36 wherein detecting the radio frequency artifact comprises using a monitor having an antenna that receives the signals.

5 39. The method of Claim 36 wherein processing the radio frequency artifact comprises using circuitry capable of monitoring multiple channels of the signals.

40. The method of Claim 39 wherein processing the voltage artifact further comprises using a slew limit circuit to limit pace artifact energy in the signals.

10 41. The method of Claim 39 wherein processing the voltage artifact further comprises using a tunable band pass filter to isolate the radio frequency artifact from ambient noise.

42. A system for monitoring signals from an implantable medical device comprising:

means for detecting a radio frequency artifact from the implantable medical device; and

5 means for processing the radio frequency artifact from the implantable medical device in order to determine where artifact occurs in an ECG and identify heart beats that are paced and heart beats that are not paced and occurrences of pacing that fail to stimulate a heart beat;

wherein the voltage artifact is excluded from heart rate  
10 determinations.

43. The system of Claim 42 further comprising a means for detecting the radio frequency artifact by radio telemetry from a remote location relative to a patient.

44. The system of Claim 42 further comprising a means of  
15 monitoring multiple channels of the signals.

45. A method for monitoring a signal from an implantable medical device comprising:

filtering voltage samples from multiple channels of the signal;  
detecting at least one of a leading edge and a trailing edge for a  
20 pulse;

measuring width of a pulse;

measuring amplitude of the pulse;

validating the pulse;

classifying the pulse; and

25 storing information about the pulse.

46. The method of Claim 45 further comprising processing the signal to determine where pacing stimulus artifact occurs in an ECG and identify heart beats that are paced and heart beats that are not paced and occurrences of pacing that fail to stimulate a heart beat.

5 47. The method of Claim 46 wherein the voltage samples are filtered to accentuate pacing stimulus artifact.

48. The method of Claim 46 wherein the voltage samples are filtered with a high pass filter to preserve sharp edges to accurately measure pulse width and amplitude.

10 49. The method of Claim 45 wherein at least one of the leading edge and the trailing edge is detected when the absolute value of the difference between two consecutive samples exceeds a threshold.

50. The method of Claim 49 wherein at least one of the leading edge and the trailing edge is detected when output of a high pass filter  
15 exceeds a threshold.

51. The method of Claim 49 wherein at least one of the leading edge and the trailing edge is detected when the time between two non-consecutive samples exceeds a maximum expected artifact rise time.

52. The method of Claim 45 wherein the width is measured by  
20 determining the difference in time between the leading edge and the trailing edge.

53. The method of Claim 52 wherein the amplitude is measured by finding a sample having the most extreme value compared to zero between the leading edge and trailing edge.



54. The method of Claim 47 wherein the pulse is validated and classified by comparing the pulse to one or more pulses stored in a database.

55. A system for monitoring a signal from an implantable medical device comprising:

- 5 means for filtering voltage samples from multiple channels of the signal;
- means for detecting a leading and trailing edge for a pulse;
- means for measuring width of a pulse;
- means for measuring amplitude of the pulse;
- 10 means for validating the pulse;
- means for classifying the pulse; and
- means for storing information about the pulse.

56. The system of Claim 55 further comprising a means for processing the signal to determine where pacing stimulus artifact occurs in an ECG and identify heart beats that are paced and heart beats that are not paced and occurrences of pacing that fail to stimulate a heart beat.

57. A monitoring method comprising:

- detecting a radio frequency artifact from signals of an implantable pacemaker;
- 20 processing the radio frequency artifact from the signals of the implantable pacemaker;
- determining where radio frequency artifact occurs in an ECG;
- identifying heart beats that are paced and heart beats that are not paced and occurrences of pacing that fail to stimulate a heart beat;
- 25 excluding voltage artifact from a heart rate determination.

58. The method of Claim 57 further comprising classifying pacing stimuli according to heart chamber location.